CASL Industry Council Meeting
12-13 April 2016
Meeting Minutes

The spring 2016 meeting of the Industry Council (IC) for the Consortium for Advanced Simulation of Light Water Reactors (CASL) was held on April 12-13, 2016 at the Aloft Hotel in Greenville, South Carolina and was led by the CASL IC Chairman Scott Thomas of Duke Energy and the new CASL IC Executive Director Erik Mader from the EPRI Fuel Reliability Program. The meeting location and logistics were excellent and the group profusely thanked Lorie Fox who was largely responsible for setting everything up so effectively.
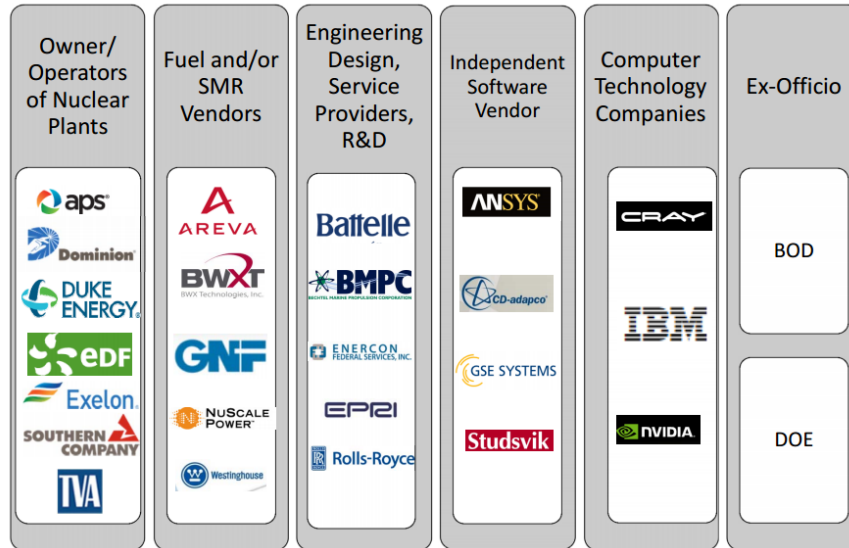

Figure 1 Organizational Industry Council Members

These meeting minutes do not capture the complete meeting details and are only intended to summarize the key discussion topics with particular focus on IC member input. The presentation materials are available online at http://www.casl.gov/industry-council.shtml. Attachment 1 shows the agenda for the meeting and Attachment 2 lists the meeting attendees and their affiliations. Attendance was by invitation only. Representatives from organizations shown in Figure 1 were invited of which 16 people attended representing 14 organizations. Seventeen members of the CASL project team participated in the meeting.

On the first day, the following technical presentations were made by CASL staff to the Industry Council participants:

- CASL Director Jess Gehin (ORNL) provided an update of CASL's recent key organizational changes:
    - Jess noted that CASL Chief Scientist Paul Turinsky is retiring and will be replaced by Dave Kropaczek (a former student of Paul's and most recently CEO and President of

Studsvik Scandpower) who will similarly take a faculty position at NCSU.

Figure 2 Jess Gehin and the Industry Council thank Paul Turinsky for his exceptional leadership and significant contributions to the CASL project as the Chief Scientist.

- o Pete Lyons is the new board chair replacing Jim Duderstadt
- o Tansel Selekler is the new DOE Federal Manager for CASL effective January 2016 and attended this IC meeting.

- IC Chair Scott Thomas organized and led the IC member overview where each IC member reviewed their organization, background and perspectives and interests of CASL. Common themes among the IC members organization types were:
    - o For the Nuclear Power Plant Operators the key interests were in advancing the state of art and understanding of the challenge problems for analytical benchmarking. Several utilities indicated an interest in bringing more core design and/or transient analyses in-house (as opposed to via fuel vendors) and were therefore interested in the eventual licensing of CASL codes. Also the impact of load follow (a.k.a. economic dispatch, flexible operations) on PCI margin or CIPS and CILC was discussed.
    - o Fuel and SMR vendors stressed their interest in the challenge problems and the improved fidelity of CASL codes are good comparisons to their own licensed codes.
    - o Engineering Design, Service Providers and R&D perspectives varied widely but also stressed the benchmarking aspects and the ability to leverage CASL lessons and products in current LWRs or future SMRs
    - o Independent Software Vendors mentioned that CASL enables acceleration in innovation at reduced costs

- Scott Palmtag presented the progress on the development of the VERA-CS core simulator where the focus was on reducing run times and enhancing the CS robustness. Roughly speaking a reactor cycle depletion can be run in 16 hours on a 1000-core machine. Scott also presented some recent work on the effect of thermal expansion on fuel pin power where the largest effect (mainly due to expansion of the core plate) can lead to pin power increases of about 2.5%.

- Erik Mader presented the status of nuclear fuel performance and reliability where, in the US, debris is the dominant leaker mechanism. No crud or corrosion-related leakers have occurred in

the US since over the last decade and only one PCI leaker (due to high residence times and hence probably related to hydride embrittlement). Grid to rod fretting (GTRF) has also decreased significantly as more-resistant fuel designs have been transitioned into full cores. The few GTRF leakers are due to baffle jetting (an internal aging issue of baffle plates) or anomalous cases not believed to be systemic to the newer fuel designs.

Erik then presented an overview of the Delivering the Nuclear Promise initiative now underway in the U.S. to reduce generation costs to make nuclear power more competitive. The purpose was to lay the context of the environment in which CASL tools will have to compete (against existing methods) in the near future. While fuel is not a line item in the initiative, it can have a significant role to play to maintain focus on fuel reliability and safety and to avoid costs associated with leakers or excess margins used in current methods. Erik's last slide ("CASL Value Proposition Questions") was the topic of much discussion throughout the meeting and is presented here for ease of reference:

Note: after the meeting it was pointed out that CILC should be included in this list.

- Andrew Godfrey presented an update on the near-term applications of VERA core simulator covering Watts Bar 1 benchmarking activities of the first 12 cycles, time-dependent WB 2 startup investigations, and fuel lattice depletion benchmarks of AP1000 and Krsko Cycle 1 for critical boron concentration and assembly power. Andrew also discussed the VERAView tool to investigate outputs in a graphical user interface.

- Brian Kendrick presented the CIPS simulation progress and path forward. MAMBA, MPACT and CTF codes are coupled to assess CIPS and CILC risks. MAMBA is the main crud tool that has an "adaptive grid" that grows its grid of volume elements to simulate crud buildup and has been benchmarked to loop and plant data with known cases of CIPS (WB1 Cycle 7) and CILC (Seabrook Cycle 5). Brian discussed the "1D" version of MAMBA that uses parameterized models for heat transfer and thermodynamics to speed up runtimes to allow full core CIPS simulations which has a drawback in predicting actual boron deposition patterns due to the mixing above spacer grids. They have ongoing efforts to benchmark MAMBA 1D versus the 3D version that uses the CFD code STAR-CCM+. Brian emphasized the need for more plant data of time-resolved axial offset, chemistry parameter, and power histories and most importantly, crud scrapes

and liftoff.

- Yixing Sung presented the progress on the DNB steamline break challenge problem that aims to improve understanding of margins to DNB (or CHF) and potentially allow for cost savings in safety analysis efforts and thermal performance improvements in fuel design. VERA-CS was used to assess the limiting case in a postulated hot-zero-power steamline break depending on core flow (high flow with RCP operational and low flow when they are not as in the case of loss of offsite power). Efforts to date show that current methods are conservative and that margins may be trimmed to reduce costs through reload fuel management changes and in regulatory compliance efforts.

- Joe Rashid presented the progress on the PCI challenge problem and discussed the 5 gaps where CASL's BISON fuel performance code may deliver value over existing methods. The gaps are:
  1. No simulation of PCMI/PCI in the 1 ½ dimensional licensed codes (e.g., Transuranus, Enigma, Frapcon, Fraptran)
  2. No prospects for simulation of GTRF and CILC in the 1 ½ D codes
  3. Load follow / flexible power operations (LF/FPO) is done at some risk that BISON's improved modeling of fuel decondititioning (i.e., crack re-cohesion modeling) may enable optimized ramp rates (faster return to power) with improved understanding of PCI margin
  4. Understanding LF/FPO impacts on plant operations requires coupled fuel performance and physics methods which are currently lacking but could be improved with VERA-CS.
  5. Used fuel management consideration of hydride reorientation & re-precipitation for high burnup fuel is empirical (based on DBTT data) and can benefit from transforming BISON into a thermal-chemical-structural code to improve industry's ability to address NRC concerns noted in the Regulatory Information Summary report. Joe showed an example where hydride reorientation may not be an issue if fuel pellet to clad bonding (in high burnup fuel) is explicitly treated due to the stress reductions calculated for a fuel/clad composite structure as opposed to just the clad bearing the load from the rod internal pressure.

- Vince Mousseau presented the update on Validation and Verification plans to benchmark the higher fidelity CASL tools to actual data and the processes involved. Vince discussed the overall approach is a "validation pyramid" where by the challenge problem parameters of interest are at the top and are successively broken down into smaller domains and eventually that domain rests within one code where V&V is straightforward. Applying uncertainty quantification (UQ) to a suite of CASL codes is a challenge since the distribution of parameters of interest is needed but not always available. Sensitivity studies are also used. Experts are used to assess likely ranges of parameters. They have begun to apply this to the CIPS challenge problem. Changing software versions is a continuing challenge but UQ is often done on frozen version of code by automating the process as much as possible so that UQ for subsequent versions is easier.

- Paul Turinsky, on behalf of his former Ph.D. student Bassam Khuwaileh, presented the uncertainty quantification and data assimilation update to investigate uncertainties in cross sections (via coupled radiation transport and sub-channel thermal-hydraulic codes). Comparisons of brute force Monte Carlo, reduced order surrogate models, and VERA-CS predictions of k_{eff}, maximum pin power, and maximum pin temperatures were used to do UQ for a single fuel assembly and a full core WB1 Cycle 1 model. Data assimilation is the more difficult task and an efficient reduced

dimensionality-based scheme was developed.

- Rich Williamson presented the BISON development progress. BISON is the fuel performance code that is part of the MOOSE-BISON-MARMOT toolset that allows 3D steady state and transient modeling of oxide fuel, pellet-to-clad gap and plenum, and cladding behaviors. The material models are only for Zircaloys but users will be able to enter their own material models for modern claddings. Application to the MPS PCMI challenge problem and LOCA and RIA were discussed. The code is largely benchmarked to Halden data and is participating in the OECD PCMI benchmark of 20 participants using 12 codes which will allow comparison to other codes and to test reactor data. Benchmarking activities are also underway in LOCA and RIA.

- Kevin Clarno presented the BWR PCI challenge problem which is in its early stages and is focused on understanding margin to failure during control blade maneuvers. The near term goal is to demonstrate the capabilities in 2018 which requires integrated neutronics, thermal-hydraulics and fuel performance applied to a sub-region of the core (such as limited fuel rods). Currently only simplified bundle designs with basic materials are analyzed but could be extended to more complex modern fuel designs and advanced materials.

- Mike Doster (NCSU) provide an overview of the Educational Program and an update on the upcoming Summer Institute. The main focus of the Education Program is to integrate CASL technology into undergraduate and graduate curricula to help develop the next generation of workers. VERA-EDU is a slimmed down version of VERA that avoid export control issues that is used to develop course modules. An undergraduate research scholar program at NCSU to recruit top students into graduate school. A summer 2015 student workshop was also held to familiarize the 27 graduate students from 9 universities to CASL technology with hands-on VERA experience. Education modules are now being developed for fuel performance, thermal hydraulics and neutronic packages that ultimately will be run under the VERA-EDU platform available to all university partners. The upcoming 2016 Summer Institute will provide a certificate to those participants who successfully complete the course of intense two-week long instruction and hands-on work with MPACT, COBRA-TF, and BISON codes in addition to lectures on multiphysics coupling, validation, sensitivity and uncertainty quantification. The Summer Institute is open to industry participants at no charge for the 2016 but future years may involve a fee.

Roundtable Discussion

At the end of the technical updates, the IC conducted a roundtable discussion in which its members provided their perspectives on the meeting and on CASL in general. Here are some of the most salient discussion topics:

Scott Thomas, Duke:
- Best wishes and a big thanks to Paul Turinsky and a big welcome to Dave Kropacezk.
- This was one of the best IC meetings so far and the presenters are to be commended.
- Bison and CIPS presentations were among the best that have been heard at the IC meetings.
- VERA's speedup is encouraging
- Steam line break LOCA is also of interest to the industry council, vendors and utilities that do their FSAR Chapter 15 licensing work and Duke has some data that could be contributed

(perhaps through their master agreement that still needs to be signed) to help benchmark the mixing effects.
- Feedback about MAMBA, IC thinks MAMBA and CIPS is the CASL big success – presentation was right on the mark. This is the nearest-term payoff to utilities and we are really close. In the next IC meeting, Scott would like to hear more about getting the same database that EPRI has in terms of plant benchmarking, plants that have had CIPS will be more than willing to grant access to the measured plant data. If more resources need to be applied in this area, then CASL should do that. It was pleasing to hear of the good interactions with EPRI BOA team. When he talks to Kenny Epperson (former Duke, EPRI, and on the BOA team), his first response is on the source term (which is not a current focus) and he wants to have comprehensive modeling of the source term.
- As far as showing value, we need to do additional benchmarking with BOA and show value with respect to BOA. If we can identify things that BOA is not modeling now and that MAMBA has the potential to do so and improve the methodology, that's a good place to focus on.

Erik Mader, EPRI:
- First IC meeting and learned a lot of new information with impressive results.
- EPRI is data rich, but codes that are currently maintained by EPRI (like BOA and FALCON) require resources that could otherwise be focused elsewhere such as emerging issues. We think that CASL provides a long-term vision of taking over and replacing those codes. But, getting to that point will be a challenge, and that main challenge is validation. We need a better grasp of how data gets shared between EPRI and CASL, and how everyone benefits from that data exchange. Need to work out the means for data contribution for validation, in cooperation with fuel vendors and utilities – what is in it for the groups that provide the data? EPRI /FRP is a global organization with members from 18+ countries that fund research to generate the data and understandings that EPRI would like to contribute to CASL. So the current export control restriction to U.S. citizens only is problematic.
- Erik was not clear of the specific value of some of the challenge problems for the utilities – returning to the theme of his lunchtime talk of the previous day. Utility-focused roadmaps (as used extensively in EPRI) detailing the value that CASL aims to deliver are needed. The CASL staff noted this has been done in the challenge problem charters, implementation plans and value proposition documents and Erik took an action to review those first.

Dominic Napolitano, Enercon:
- Impressed with the progress on the computational speedup. Other issue is hardware – from a practical point of view, how many cores can you get down to? NuScale has 100s of cores, most vendors have 10s? 1000 cores was identified by the group as about right.
- Quite impressed with the SQA and V&V with the Bison code development – going in the right direction
- Paul's discussion of UQ was also quite impressive
- Load following is going to be an increasing emphasis, and its implication on fuel performance
- Incorporating other parts of the system for full thermal hydraulic analysis – having parametric model for SMRs with natural circulation for power ascension

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Ian Stevenson, Simulia
- Simulia very interested in continued collaborations and expressed kudos to the team for the impressive work to date.

Jim Banfield
- GE perspective to get VERA-CS to run faster and on smaller systems
- For BWRs, there is some progress being made and transients are significant concerns for GE/GNF. Would like to see more transient development for BWRs.

Tyrone Stevens, Exelon
- PCI failures at Braidwood remain his interest where cycle 13 startup with slow ramp rates (½% per hour + 24 hour stress relief hold) and they still had a failure. He feels that they still do not have a true idea of margins. Subsequently, Exelon implemented very stringent operational restrictions to avoid MPS PCI, including placing fresh WABAs into first burn, implemented tight AOA control. Implemented short ramp rates, long coast downs to 25-26 days, which impacts the delta kW/foot. They are beginning to relax the implementations that they put in place back to the level of industry (vendor and EPRI) guidelines. Really interested in using Bison and VERA-CS to assess the margins, and expects that they have MPS defects still. Want to have a tool to assess the relaxations, and they are adding complexity of the load following. Licensing of the codes for PCI assessment isn't required at this point since they only want to get back to current industry guidance.
- Load following will change the Xe depletions, control rods moving in and out of the core. They were the first utility to find the MPS, because they had high capacity factors and short outages. They were closing the gap between fuel and pellet during the first cycle, and then contact during second cycle startup. IFBA pellets were the cause of the pellet chipping but are now being run through the APVIS pellet inspection system.
- How do you do core design for load following? Exelon is not currently doing anything differently in core design

Bob Martin, BWXT:
- He does not see VERA as a licensing tool, but he does see it as a backstop tool to validate models. Question becomes software quality assurance.
- To support industry applications, an Augmented Quality Program should be followed that facilitates commercial grade dedication as outlined in EPRI NP-1025243, Rev. 1, 'Plant Engineering: Guideline for the Acceptance of Commercial-Grade Design and Analysis Computer Programs in Nuclear Safety-Related Applications'. To do so still requires much of the administrative and V&V documentation required for NQA-1 qualification; however, the ultimate responsibility for code applicability, related uncertainties, and nonconformance/error reporting is left with the user. Communication of errors should be one of the objectives of a User Group, which would partially address the nonconformance/error reporting QA requirement.
- Interested in code scaling (comparison of varying complexity in computer architecture) which is an essential part of the process applicable to the testing, analysis and verification of the codes. He recommends that some effort be applied to code scaling.
- Bob noted that BWXT has a rather large test (very tall loop) facility (from mPower work) that is intended to be given over to the DOE to be operated as a user facility that may provide prototypical experimental data to benefit the industry, CASL included.

Al Wells, Areva:
- Interested in translating CASL code capability into Areva new methods. Want to see a bridge between high fidelity codes and what they can really get licensed by NRC. Interested in providing data to support the effort.
- Generating new methods and getting them licensed by the NRC is quite expensive, want to avoid potential roadblocks in finding a balance between high fidelity modeling and test data

Zeses Karoutas for Bob Oelrich, WEC:
- Liked Mader's last slide summarizing key problems CASL should tackle. Agrees with CRUD being the highest priority, especially if can reduce reload batch size by 4 assemblies. More comparisons with BOA and confidence. How to get there is a big question?
- Other area of PCI and load-following, mentioned by Tyrone, is another important area moving forward, even if we do not currently have PCI leakers. Validation of the BISON code to the largest database available is needed.
- Application of tools for safety analysis, really do need to submit the tools to NRC (Steam line break is one example), applying to RIA and other transients is pertinent and important moving forward so we can determine if we see value added. If so, when do we begin to start on seriously thinking about it? Jess noted that NRC needs sufficient advanced notice of such and an effort and Kathleen added that it typically has to be tied to a reload licensing effort but it has to be licensed for any utility to commit to using CASL codes. Past situations were discussed where national labs have licensed codes which may get around this Chicken-and-Egg situation.

Jason Young, DUKE
- Believes CIPS is the easiest path to demonstrate to the industry that you can save the industry money. Show a more definitive CIPS risk analysis (e.g., more than BOA's high or low risk assessments) to quantify the extent of the axial offset. This will require enhanced source term accuracy. Core designers are frustrated by the seemingly arbitrary threshold for CIPS risk that necessitate redesigns.
- Bison and Vera-CS work in terms of software quality and unit testing are very promising, and should provide confidence to others down the road.

Brian Elder, TVA:
- Confirms that the importance on CIPS and that is probably the quickest, easiest way to show the value of CASL. Would like to see MAMBA-1D versus MAMBA-3D versus BOA benchmark. Knowing the consequences of accepting a higher risk for CIPS is necessary. We should look into using the Watts Bar data and other plants where there has been mild CIPS, and compare the tuned MAMBA-1D predictions to actual plant data.
- Beyond that TVA does not view PCI as limiting for its PWRs, but is particularly very interested in PCI analysis for BWRs – Browns Ferry PCI failure that they had recently would be interested in seeing BISON + VERA analysis of.
- Impressed with what he observes as progress in the speedup of the runtimes although this was his first IC meeting.

Bob Wall, Bechtel Marine Propulsion:

- Overall, CASL is working on the right things --- liked Kevin Clarno's slide in terms of what the meaning of done is – product needs to be practical and accepted by users.
- Encouraged with Vince Mousseau's discussion on strategy and direction for VV/UQ – UQ is challenging for high fidelity multiphysics.
- The Education Program is very impressive.

Kathleen Parrish, APS:
- APS is doing in-house core design and transient analysis. Can see potential for CASL codes, including BISON analysis of fuel stored in dry cask storage.
- Interest in performing CIPS analysis for load-following. Palo Verde costs go up considerable, payroll is the largest part of the generating costs. Use of codes to assess the stressing of their cores in ways not planned for them to be stressed provide an opportunity for CASL to provide value. Work, if approved, would initially be done internally, for non-licensing studies. But, it is likely that that type of work will get pulled into licensing space. Any significant implementation of the CASL codes would require that they be licensed.

Dan Ingersoll, NuScale:
- Meeting venue was good, pace of presentations was good with plenty of time for Q&A and an appropriate amount of material was presented; consider partial debrief at the end of the first day.
- Wanted more information about the description of what has changed since the last IC meeting, and what has been accomplished since the last IC meeting. What will you be doing over the next 4 years towards completion – that will be very different for different tools, like MAMBA-1D variables. Want to have a clear answer to what will you be delivering on each component at the end of phase 2.
- Agree that CRUD/CIPS and PCI has high impact potential
- Wanted to see more about experimental validation, still rely on integral type validations. Need to hear more about where CASL is lacking separate effects data, and where might more experiments be needed? Recommend a gap list of what test data is needed to validate the newly added physics.

Jon Ryan, CD-Adapco:
- Excellent meeting, but he wants to better understand how the commercial vendors help complement the CASL tools.
- They want their products (like Star-CCM+) to be "used and useful".

Jess Gehin
- Outstanding feedback, which strengthens the need for particular aspects of our work, we will make sure that we continually evaluate our plans and re-prioritize to match the industry needs and observations.
- Actions will be taken and reported at the October IC meeting and the IC members' time and effort to support CASL is very much appreciated. Thank you.

Action Items

The next IC meeting should:

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1. Have an expanded discussion on MAMBA and the CIPS challenge problem as that is identified as the nearest-term area to provide real value to operators.
2. Review the data needs for validation and the framework, mechanisms, and incentives for data contribution.
3. Erik Mader to review the challenge problem charters, implementation plans and value proposition documents to evaluate if they clearly detail the value to operators and report back to the IC.
4. Consider adding a debrief session at the end of the Day 1 activities.
5. Presentations should clearly identify what's new.

Meeting Logistics

The next in-person meeting is scheduled for the October 11-12, 2016 at Oak Ridge.
The meeting was adjourned at noon April 13, 2016 and was followed by the inaugural VERA Working Group meeting which is summarized in separate meeting minutes also located at
http://www.casl.gov/industry-council.shtml.

Figure 3   The Industry Council meeting room.

Minutes prepared By: Erik Mader (new CASL IC Executive Director) with additions from Brian Wirth (FMC focus area lead).

Attachment 1: Agenda

CASL Industry Council Meeting

Tuesday, April 12, 2016 – Wednesday, April 13, 2016
ALOFT Hotel Greenville Downtown
5 N Laurens St, Greenville, SC 29601
Meeting Room: Converge

Meeting Objectives: The mission of the Industry Council (IC) is to ensure that CASL solutions are "used and useful", and that CASL provides effective leadership advancing the Modeling and Simulation state-of-the art in the nuclear industry. This meeting provides an opportunity for the exchange of information about CASL's research and activities to:

- Provide an opportunity for engagement between industry stakeholders and CASL researchers.
- Present and seek feedback on the progress on CASL's R&D activities and plans.
- Discuss CASL and industry priorities to ensure that they are aligned.
- Identify strategic collaborations between industry and CASL Focus Areas.

Tuesday, April 12

8:30	Welcome, Meeting Objectives and Introductions	Scott Thomas
9:00	CASL Update	Jess Gehin
10:00	Break	
10:15	IC Member Overviews	Scott Thomas
11:15	VERA Core Simulator Development Progress	Scott Palmtag
11:45	Working Lunch – Delivering the Promise Presentation	Erik Mader
1:00	Application of VERA-CS to Watts Bar and other plants	Andrew Godfrey
2:00	CIPS Simulation Progress and Path forward	Brian Kendrick
2:45	DNB Steamline Break Analysis Challenge Problem Progress	Yixing Sung
3:30	Break	
3:45	PCI Capability Development and Challenge Problem Progress	Joe Rashid
4:30	V&V Applications and Approaches for Challenge Problems	Vince Mousseau
5:30	Adjourn	

Wednesday, April 13

8:30	Update on Bison Development and V&V Plan	Rich Williamson
9:30	Progress in modeling BWRs for PCI Challenge Problem	Kevin Clarno
10:00	Break	
10:15	CASL Education Program and Summer Institute	Mike Doster
10:45	Industry Council Member Comments/Input	Scott Thomas
11:45	Wrap up - Action items and next meeting	Erik Mader
12:00	Adjourn	

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Attachment 2: Industry Council Attendees

Industry Council Members

Scott Thomas	Duke Energy	Scott.Thomas@duke-energy.com
Kathleen Parrish	Arizona Public Service	Kathleen.Parrish@aps.com
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